

THE ROLE OF FRAGMENTATION IN INTERACTION OF METEOROIDS  
WITH THE EARTH'S ATMOSPHERE

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As a rule, when analyzing the mechanism of quasi-continuous fragmentation (QCF) it is assumed that fragments separated from the parent meteoroid (PM) are of equal initial mass. In reality, this may not be so. A major difficulty is the lack of observational data on the function of the fragment initial mass distribution and so one must resort to theoretical modeling. Let us consider a discrete distribution which excludes to a certain extent some mathematical difficulties. We assume that during flight, fragments constantly separate from the PM forming several groups. In this case, the role of this distribution is reduced to mere addition of brightness from separate groups of fragments of the given weight factor. If  $M_i$  is the fragment mass maximum estimated by the formula (BABADJANOV and KRAMER, 1965)  $M_i \approx 4/3 \pi \delta x^3$  (where  $\delta$  is the fragment density and  $x$  is the depth of heating), then the rest of fragment masses will be  $M_{oi} = M_i / K^{i-1}$ , where  $K = 2$  or  $\sqrt{10}$ , or  $10$ . Let  $P_i$  be a part of the PM mass that became fragments with the particles mass  $M_i$ , then the total number of fragments of each kind will be  $N_i = M_i / M_0 P_i$  ( $M_0$  is the initial mass of PM). Thus, if  $I_i(h)$  is the intensity at the height  $h$  of a definite kind of fragment  $i$ , then the meteor brightness curve taking into account the discrete distribution can be found by:

$$I_B(h) = \sum_{i=1}^n I_i(h) P_i \quad (1)$$

The calculation results (but without taking deceleration into account) are given below. To illustrate this, a slow fragmentation process has been considered when the lifetime  $\tau_H$  of fragments separated at the moment when fragmentation began until their complete evaporation is less than that of the total PM lifetime  $\tau_0$  (BABADJANOV and KRAMER, 1968).

Meteoroid and fragment parameters were chosen as follow:  $M_0 = 3g$ ,  $V = 30 \text{ km/s}$ ,  $\cos Z_R \approx 0.6$ ,  $H^* = 6 \text{ km}$ ,  $\Lambda = \Lambda' = 1$ ,  $A = 1.5$ ,  $A' = 1.21$ ,  $\rho_H = \rho = \delta = 3.4 \text{ g/cm}^3$ ,  $Q = 8 \times 10^{10} \text{ erg/s}$ ,  $i = 5$ ,  $P_1 = 0.1$ ,  $P_2 = 0.2$ ,  $P_3 = 0.4$ ,  $P_4 = 0.2$ ,  $P_5 = 0.1$ , the height of fragmentation starting point is  $90 \text{ km}$ . Here  $V$  is the velocity of a meteoroid;  $H^*$  is the scale height;  $Z_R$  is zenith distance of the meteor radiant;  $Q$  and  $Q_g$  are the energies of evaporation and fragmentation respectively;  $\Lambda$  and  $A$  are the heat transfer coefficient and shape factor of PM;  $\Lambda'$ ,  $A'$  are the analogous values of a fragment;  $\rho_H$  is the atmospheric density at the height of meteor appearance;  $\rho$  is the atmospheric density at any point on the meteor trajectory; and  $\delta$  is density of PM. The table below shows this variation  $I_B$  of meteor brightness (in units of maximum magnitude) with the height  $h$ . For comparison, meteor brightness is also presented for the case of PM disintegrating into fragments of mass  $M_{o3} = M_0 / 10$  and labeled  $I_3$ . As is seen from the table, the mass distribution has practically no effect on the shape of the brightness curve. The value of maximum brightness is roughly the same for different fragment masses and remains at about the same

height. The heights of meteor disappearance differ little from each other. If we consider  $P_i$  as some other function, the result will be essentially the same.

h km	90	88	86	84.64	84.41	83	81	79	77.89	77.6
$I_B$	0.00	0.730	0.960	1.00	0.996	0.941	0.630	0.145	0.00	-
$I_3$	0.00	0.774	0.958	0.988	0.992	0.902	0.607	0.103	$7.10^{-3}$	0.00

It is common knowledge that photographic observations using the instant exposure method give the most complete information on the process of meteor phenomenon origin. (BABADJANOV and KRAMER, 1965; BABADJANOV and KRAMER, 1968; BABADJANOV, 1983). Studying a succession of such meteor photographs, BABADJANOV and KRAMER (1965) concluded that during flight, a meteor coma might take different shapes, from a simple dot to a complete head and tail. A drop-like shape was the most typical. Since the question of the formation and further evolution of a meteor coma along its trajectory was of great interest, the quasi-continuous fragmentation theory was improved by including fragments deceleration (BABADJANOV et al., 1984).

This theory enables one to study not only meteor brightness curves and wakes, but also model the instantaneous images of the luminous coma along the whole of the visible trajectory of a meteor. The following simplifications were suggested: (a) PM deceleration is small; (b) all fragments are of equal initial mass  $m_o$ ; (c) the luminosity is due mainly to atoms and molecules evaporating from fragment surfaces, not from that of PM; (d) formulae of the simplest physical theory of meteors are true both for fragments and for PM (LEVIN, 1956); and (e) that the sizes of the PM and its fragments are much less than the distances between them so that all can be considered to be points. Given these assumptions, expressions for the total meteor intensity and brightness curve were derived as well as the visible intensity profile through the luminous coma.

The analysis revealed the dependence of  $I_B$  to be determined by physical parameters of PM and fragments through combinations of the special parameters  $\gamma$ ,  $\gamma_1$ , and  $\lambda$  as defined by BABADJANOV, et al. (1984).

$$\gamma = \frac{\Lambda A V^2 \rho_H^{H*}}{6Q_g (M_o \delta_o^2)^{1/3} \cos Z_R} ,$$

$$\gamma_1 = \frac{\Lambda' A' V^2 \rho_H^{H*}}{6(Q - Q_g) (M_{oi} \delta_{oi}^2)^{1/3} \cos Z_R} , \quad \lambda = \frac{\beta \rho_H}{2V^2} .$$

These parameters can be obtained from comparison of theoretical and observed profiles of instantaneous meteor images. The figures show the evolution of instantaneous image profiles along the meteor trajectory for different times  $t$ . The parameters selected were as follow:  $M_o = 30g$ ,  $V =$

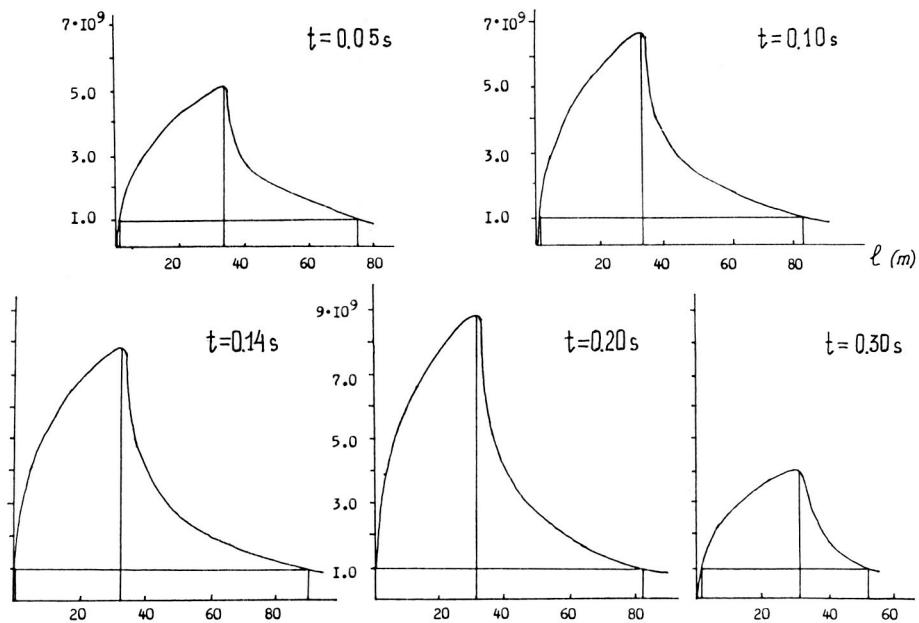


Fig. 1 The evolution of instantaneous image intensity (ergs/S) profiles along a meteor trajectory at different times  $t$ , for exposure times  $5.6 \times 10^{-4}$  S.

60 km/s,  $H^* = 6$  km,  $\cos Z_R = 0.6$ ,  $\lambda = 0.13$ ,  $\gamma = 0.14$ ,  $\gamma_1 = 1$ . The intensity  $I_B$  is in erg/s (Y-axis) and distance in meters  $\ell$  (X-axis). The exposure time  $\tau_\theta = 5.6 \times 10^{-4}$  s. The horizontal line gives the threshold brightness value equalling about  $2 \times 10^9$  erg/s. Thus, we may conclude that the profile of a meteor instantaneous image evolves with time as does the visible size of the luminous coma. This is in good agreement with observational data obtained by instant exposure.

#### References

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